SolarPACES

Heliostat Performance Testing Guideline

– Status Update Sept. 2017

Marc Röger

SolarPACES Task III Meeting, Santiago de Chile
25.09.2017

DLR

Overview

1 Objective of Guideline

2 Timeline and Status

3 Overview of Guideline with Focus on Updates

4 To Do’s to Get v1 Launched

1 Objective of Guideline

Objective of Guideline

- Enable comparison of different heliostats on an objective, scientific, but practical level
- Homogenize content of test certificates of different qualification centers
- Facilitate bankability of heliostats

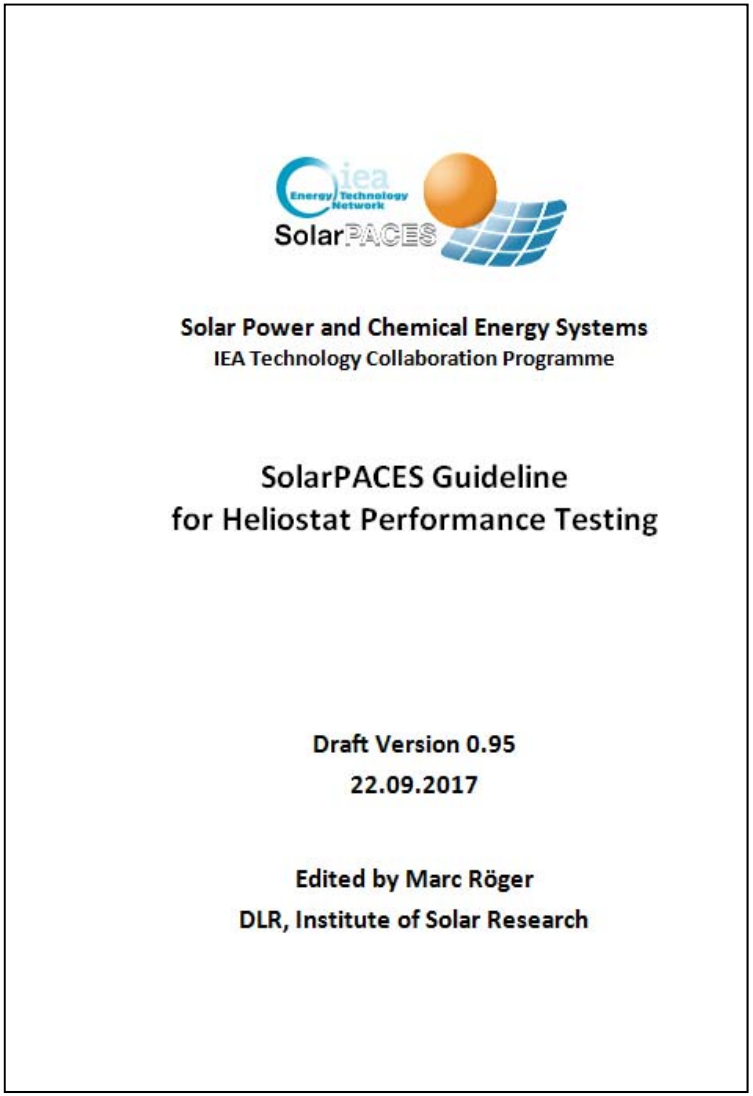
→ **The guideline for heliostat performance testing** contains an *internationally reviewed*, *concisely defined parameter list* to *describe heliostats* and their *performance*. Additionally, it suggests *measurement techniques* to derive the parameters.

Target Group: Industry, Research/Qualification Centers

2 Timeline and Status

Aug. 2014 First Parameter List	Aug. `14: List of parameters & measurement techniques	SolarPACES `14: Presentation& Discussion	Dec. `14: Latest input to parameter list
Sept. 2015 Draft Parameter List	Email discussion to get final parameter & measurem. lists	SolarPACES `15: Presentation of draft parameter & measurement lists	(Preparation of Scientific Journal Paper)
Oct. 2016 1st Draft Guideline v0.9	Oct `16: 1st (word) draft guideline v0.9	SolarPACES `16: Presentation / Discussion of v0.9 in Task III	Dec. `16: Feedback from industry and F&E
Dec. 2017 Guideline v1.0	2017 Integration of feedback	SolarPACES `17: Update	Dec.`17 Guideline v1.0

3 Overview of Guideline / Updates


Solar Power and Chemical Energy Systems
IEA Technology Collaboration Programme

SolarPACES Guideline
for Heliostat Performance Testing

Draft Version 0.95
22.09.2017

Edited by Marc Röger
DLR, Institute of Solar Research

Status: 22.09.17

Internal draft version 0.95

- Includes feedback from CIEMAT, DLR, CNRS-PROMES, Fraunhofer ISE, Abengoa, CSP Services, sbp Sonne
- v1.0 planned to be sent out in Dec. 2017.

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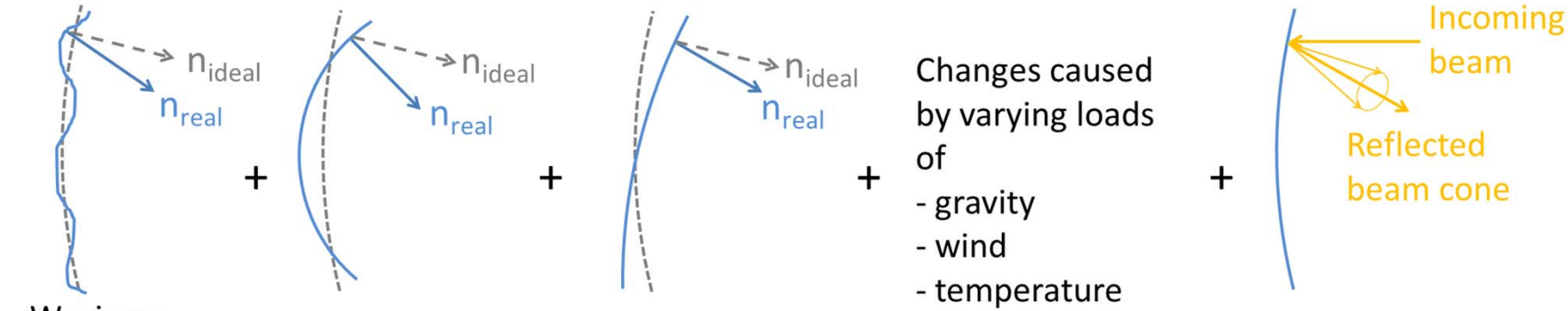
3. Symbols and General Definitions 2

- Definition of *Global Coordinate System (GCS):*
  right-handed; *z* vertical up, *y* north (northern hemisphere), *y* south (southern hemisphere)
  Origin: must be defined, recommended: north-south symmetry plane of the solar field at tower ground level or for cylindrical receivers central axis at ground level
- Definition of *Heliostat Coordinate System (HCS)*:
  right handed, moves with helio, *z* being the heliostat surface normal pointing away from the mirror surface and *y* being the vertical axis projected into the concentrator plane
  Origin: must be defined, recommended: on the concentrator central axis so that the lowest z value of the reflective surface is (close to) zero and the rest of the z values are positive.
- *Definitions of Angular Errors (*Contour, Canting, Slope, Specularity*)
- *Naming Convention for Angular Deviations
- **Concentrator Elevation and Azimuth*
- Further Definitions (*Mirror Panel, Concentrator, Heliostat*)

Definitions of Angular Errors (*Contour, Canting, Slope, Specularity*)

CONCENTRATOR



Contour Error ($SD_{contour}$)

Canting Error ($SD_{canting}$) = Alignment Error

$\Delta\, SD_{grav}$
$\Delta\, SD_{wind}$
$\Delta\, SD_{temp}$

Specularity Error (***Spec***) = Roughness Error

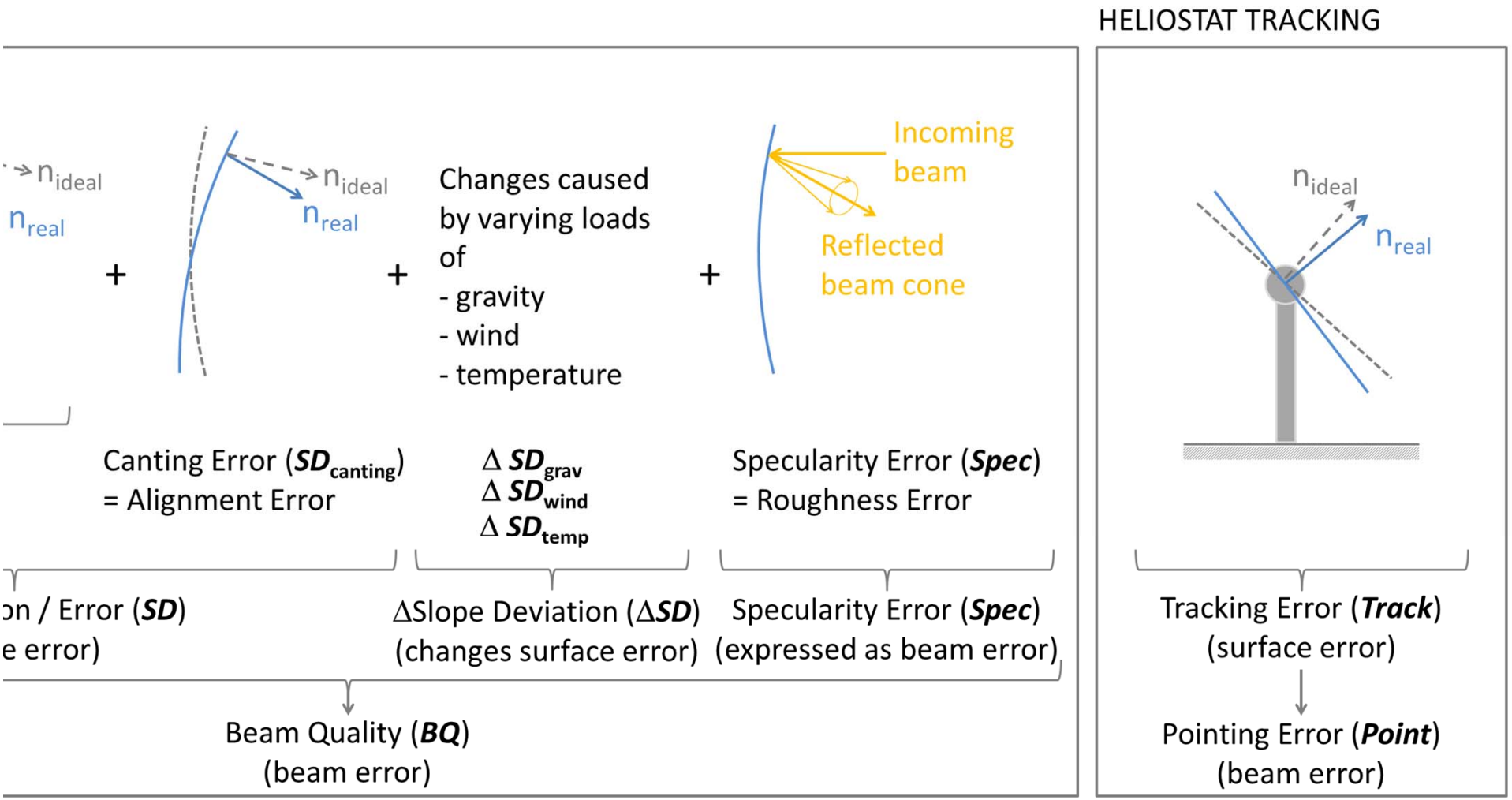
Slope Deviation / Error (***SD***) (surface error)

ΔSlope Deviation (Δ***SD***) (changes surface error)

Specularity Error (***Spec***) (expressed as beam error)

Beam Quality (***BQ***) (beam error)

Definitions of Angular Errors (*Contour, Canting, Slope, Specularity*)



Naming Convention for Angular Deviations

Part 1	Part 2	Part 3
SD contour canting …grav …wind …temp *Spec* *BQ* *HQ* *Track* *Point* *TotHelioDisp* *TotBeamDisp* *astigm*	x y 2D (xy)	RMS MEAN STD / σ mat vec

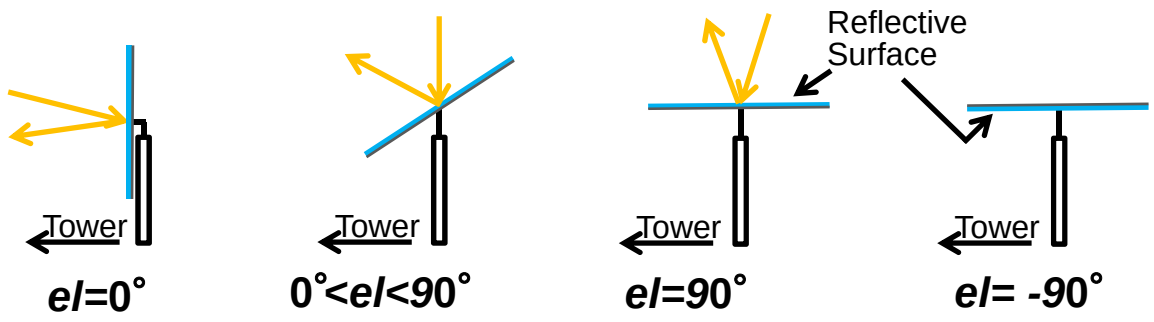
Part 1-2-3 (recommended)

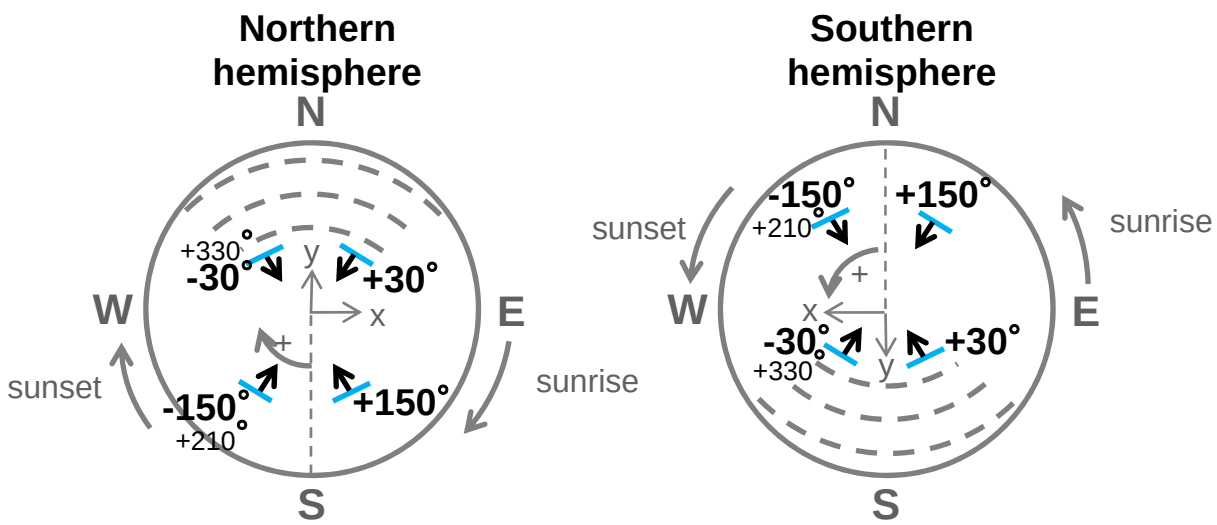
Part 3-1-2 (allowed)

Naming Convention for Angular Deviations: Examples

Example	Type of value	Nomenclature Option 1 Part 1-2-3 (standard)	Nomenclature Option 2 Part 3-1-2 (allowed)
Slope Deviation in *x*-dir.	RMS	$SD_{x,RMS}$	$RMS_{SD,x}$
	Standard dev.	$SD_{x,STD}$	σ_{SDx}
	Mean value	$SD_{x,MEAN}$	$MEAN_{SD,x}$
	Matrix values	$SD_{x,mat}$	$mat_{SD,x}$
Tracking Error in *y*-dir.	RMS	$Track_{y,RMS}$	$RMS_{Track,y}$
	Standard dev.	$Track_{y,STD}$	$\sigma_{Track,y}$
	Mean value	$Track_{y,MEAN}$	$MEAN_{Track,y}$
	Time series	$Track_{y,vec}$	$vec_{Track,y}$
Beam Quality (always 2D)	RMS	BQ_{RMS}	RMS_{BQ}
	Standard dev.	BQ_{σ}	σ_{BQ}
	Mean value	BQ_{MEAN}	$MEAN_{BQ}$
	Time series	BQ_{vec}	vec_{BQ}

Concentrator Elevation and Azimuth





Concentrator Elevation:
Defined to be the angle between the concentrator normal and the horizontal plane with mirror surface facing ground being -90° and mirror surface facing sky +90° elevation

Concentrator Azimuth:
Defined to be the angle between the concentrator normal and negative *y*-direction of the GCS (i.e. south direction for northern hemisphere, north direction for southern hemisphere) projected on the horizontal plane. The angle is measured clockwise in the northern hemisphere and anticlockwise in the southern hemisphere.

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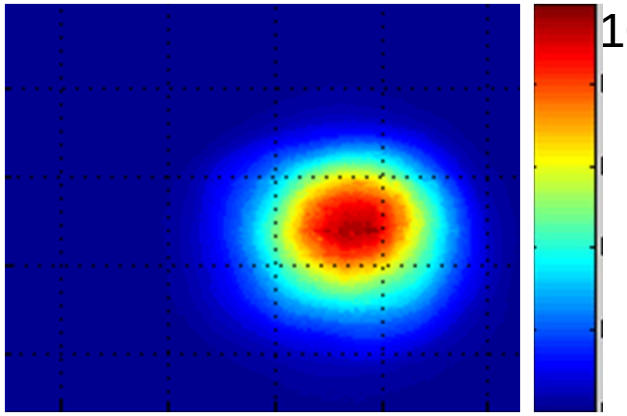
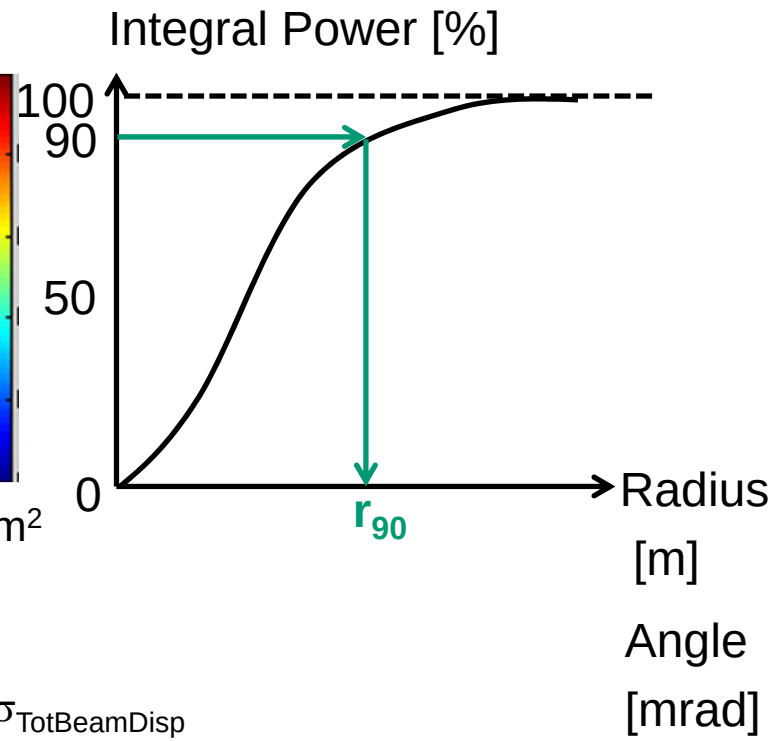
OLD METHOD: Shape / Beam Quality

Beam Quality by Flux Density Distribution

Beam on Target



Flux Distribution on Target W/m^2



Values like

- Total Beam Dispersion $\sigma_{TotBeamDisp}$
- “90° -cone power angle”
- Flux profiles
- Etc etc

OLD METHOD: Shape / Beam Quality

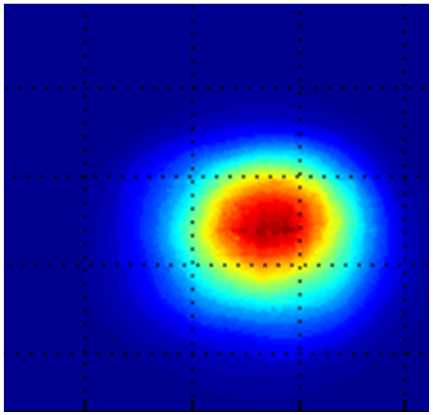
Beam Quality by Flux Density Distribution

Total Beam Dispersion $\sigma_{TotBeamDisp}$ as measured on target

Does not describe the heliostat properties properly

Because it depends on

- Astigmatism,... (day of time / year / location of heliostat)
- Meteorological parameters (sunshape, scattering)

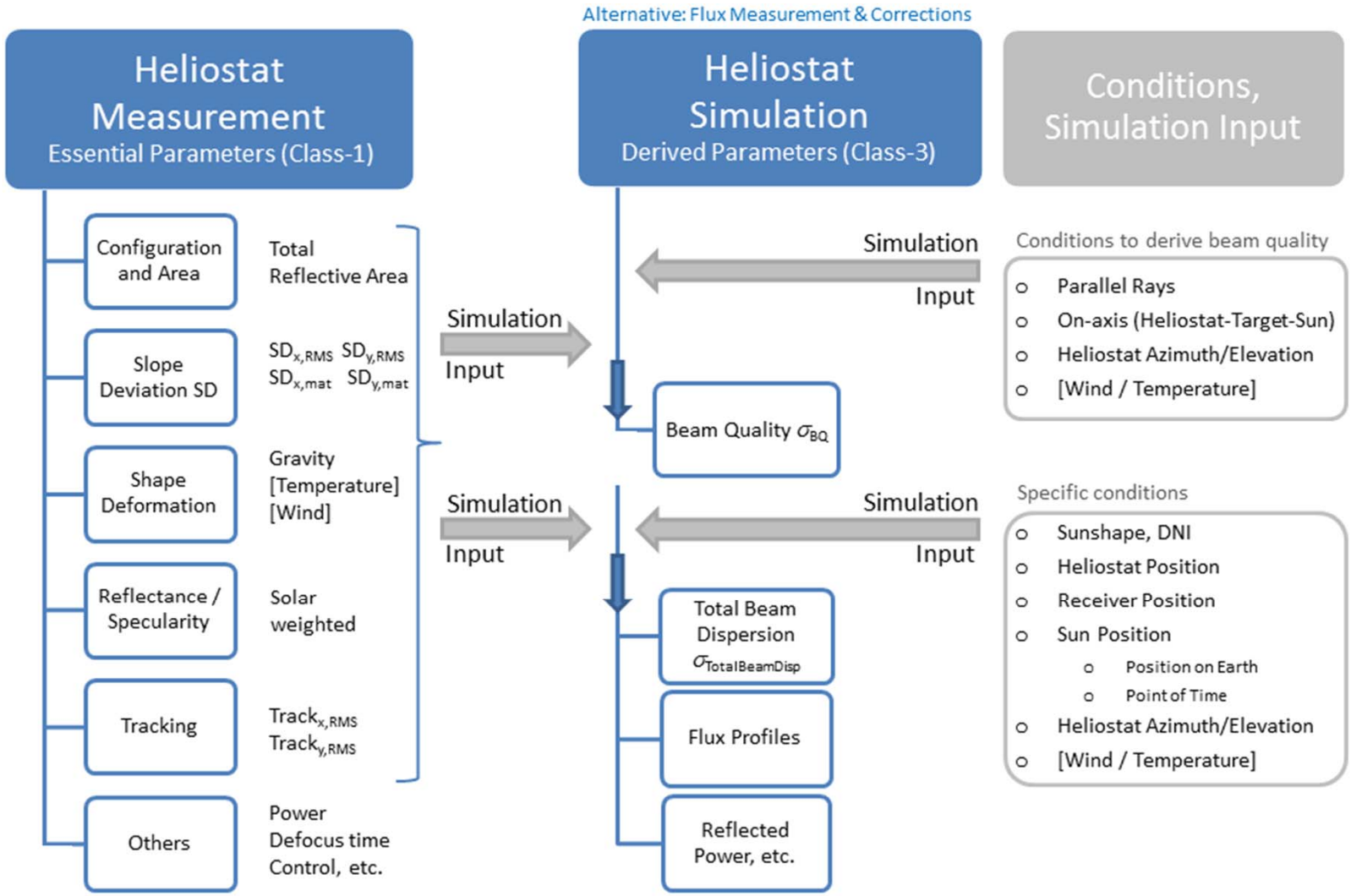


We would need the beam quality σ_{BQ}

$$\sigma_{BQ} \approx \sqrt{\sigma_{TotBeamDisp}^2 - \sigma_{sun}^2 - \sigma_{astigm}^2}$$

measured not easy to account for

NEW METHOD: Guideline, Sec. 4: **Underlying Philosophy**



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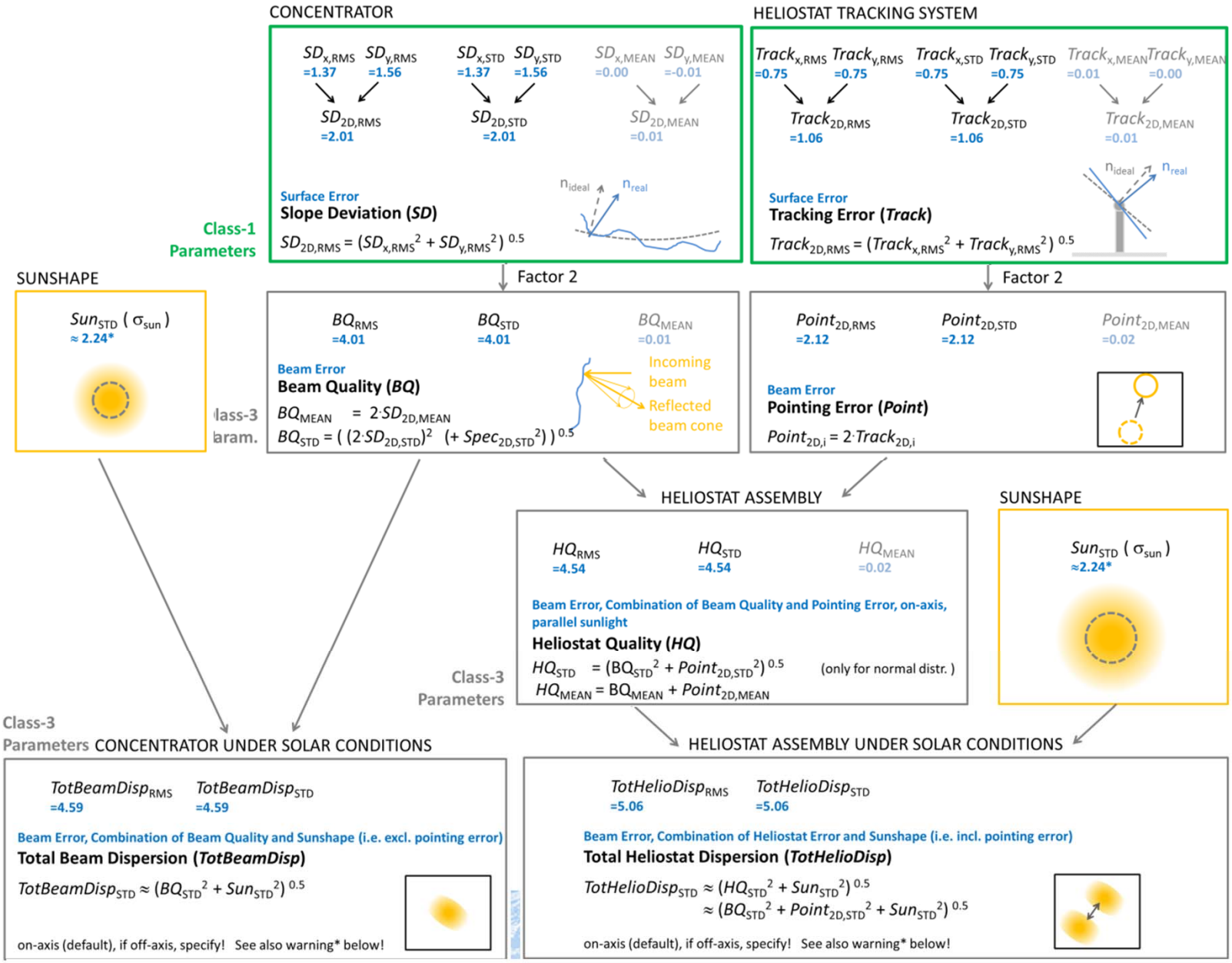
Guideline, Sec. 4: **Underlying Philosophy**

The essential parameters (class-1) are *mandatory* to describe heliostat performance according to this guideline. In general, all these parameters must be given for comprehensive description of the heliostat performance..

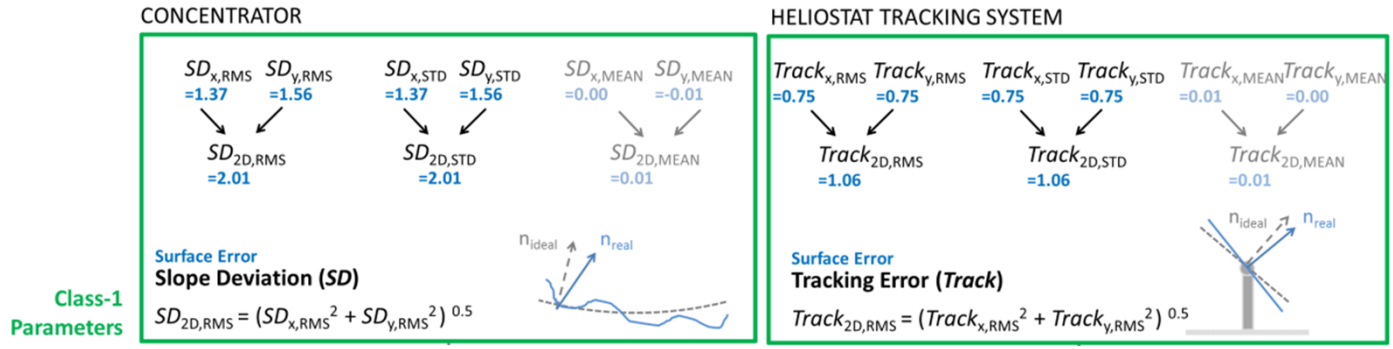
Additional descriptive parameters (class-2) as part of an *extended list* deliver additional, but not essential information. They may be additionally given.

Beam shape parameters (class-3) can be derived from class-1 parameters by *raytracing*, or are *not easily measurable under defined conditions* in industrial practice. Essential parameters should be preferred to define heliostat performance instead. However, beam shape parameters can be additionally used for their *illustrative character*.

Guideline, Sec. 4: **Underlying Philosophy**



Guideline, Sec. 4: **Underlying Philosophy**



The good thing is that according the guideline, only the class-1 parameters (*SD* and *Track*) have to be given to define the quality of the heliostat.

The other parameters (*BQ*, *Point*, *HQ*, *TotBeamDisp*, *TotHelioDisp*) are class-3 parameters and are not essential.

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Guideline, Sec.5/app.A: Terms and Definition of Heliostat Parameters

Appendix A: Terms and Definitions of Heliostat Performance Parameters

A.1 Essential Parameters (class-1)

n	Parameter Name (Symbol)	Unit	Value Example	Variable Type	Definition
HELIOSTAT SETUP					
1	HelioSetup.General.Type	-	T-shape	string	Construction principle [T-shape / carousel / sloped axes heliostat /steel frame / bubble enclosed / rotating field / ganged heliostats (multiple facets)/ venetian blinds / Yoke / shared support / dual modul drive / etc.]
2	HelioSetup.Axes.Alignment	-	[az. axis vert.; el. axis horiz. 20° to horizon]	string vector	Orientation of the [first; second] tracking axis while the second axis is defined as the one which moves with the first axis. e.g. [azimuth axis vertical; elevation axis horizontal / inclined to horizon 20° or interval 20 to 40° / equatorial mounting / English mounting, etc.]
3	HelioSetup.Axes. HeightOfSecondaryAxis	m	2.14	single	Height of center of secondary axis (mostly elevation axis) from ground
4	HelioSetup.Axes. DistanceConcToSecondaryAxis	m		single	Distance from nearest concentrator surface point to point of intersection of first and second tracking axis. This is often approximately the length of the cantilever arm between the center of the horizonal elevation axis and the mirror plane.
5	HelioSetup.Conc.Outline	-	rectang.	string	Outline of concentrator [rectangular / round / pentagonal / hexagonal / etc.]
6	HelioSetup.Conc.Dimension	m	[4; 4]	single vector	Concentrator size in [x; y] direction (rectangular outline) or diameter (round outline) or [min; max] diameter (rotationally symmetric outline) or other description via edge lengths (other outlines)
7	HelioSetup.Conc.ReflectiveArea	m^2	15.9	single	Reflective aperture area of concentrator (excluding gaps between facets)

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Guideline, Sec.6/app.B: **Determination / Measurement of Heliostat Parameters**

Appendix B: Measurement / Determination of Heliostat Performance Parameters

B.1 Essential Parameters (class-1)

n	Parameter Name (Symbol)	Provided by (Lab / Man)	Technique for Derivation of Parameter
HELIOSTAT SETUP			
1	HelioSetup.General.Type	Lab/Man	n/a
2	HelioSetup.Axes.Alignment	Lab/Man	Inclinometer, protractor
3	HelioSetup.Axes. HeightOfSecondaryAxis	Lab/Man	(Laser) distance meter, tape measure, etc.
4	HelioSetup.Axes. DistanceConcToSecondaryAxis	Lab/Man	(Laser) distance meter, tape measure, etc.
5	HelioSetup.Conc.Outline	Lab/Man	n/a
6	HelioSetup.Conc.Dimension	Lab/Man	(Laser) distance meter, tape measure, etc.
7	HelioSetup.Conc.ReflectiveArea	Lab/Man	(Laser) distance meter, tape measure, etc.
8	HelioSetup.Conc. NumberPerHeliostat	Lab/Man	n/a
9	HelioSetup.Facet.Outline	Lab/Man	n/a
10	HelioSetup.Facet.Dimension	Lab/Man	(Laser) distance meter, tape measure, etc.
11	HelioSetup.Facet.Number	Lab/Man	n/a
12	HelioSetup.Facet.Type	Lab/Man	n/a

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Guideline, Sec.7:
Reporting

Table 3: Example of a heliostat performance test report (excerpt)

HELIOSTAT PERFORMANCE TEST	
Photo or simplified scheme of general heliostat setup	
Heliostat manufacturer name	HeliostatFactory
Name of heliostat model	Superb
Serial number or other identifier	P4
Total number of heliostats investigated	1
Name and address of testing laboratory	R&D Testing Center, Street Name, City, Country
Testing location	Plataforma Solar de Almería, 04200 Tabernas, Spain
Date of testing period	30.04.17 - 30.07.17
Date of erection of heliostat	'01.04.17
Reference to guideline version	SolarPACES Heliostat Performance Guideline v1.0
Report format	This report and data CD
Date, signature and stamp of testing lab.	

HELIOSTAT PERFORMANCE TEST – PARAMETERS (excerpt)					
n	Full Parameter Name (Symbol)	Value	Unit	Meas.Technique	Measurement Report
1	HelioSetup.General.Type	T-shape	-	-	-
	...				
17	Optics.Conc. RealShape_SD_RMS	1.6	mrad	Deflectometry	MeasRep1.pdf
18	Optics.Conc. RealShape_SDx	CD	mrad	Deflectometry	MeasRep1.pdf
	...				
50	Cost.Specific	120	€/m²	-	CostReport.pdf

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	1
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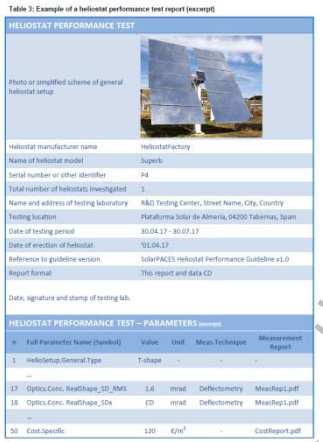
Guideline, Sec.7: **Reporting**



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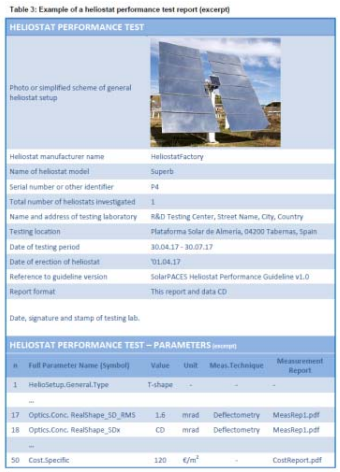
Guideline, Sec.7:
Reporting



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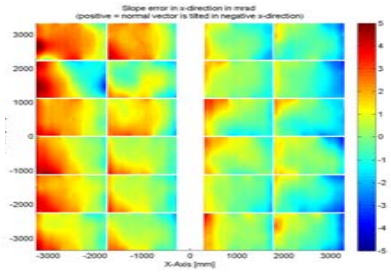
Serial number or other identifier	P4
Total number of heliostats investigated	1
Name and address of testing laboratory	R&D Testing Center, Street Name, City, Country
Testing location	Plataforma Solar de Almeria, 04200 Tabernas, Spain
Date of testing period	30.04.17 - 30.07.17
Date of erection of heliostat	'01.04.17
Reference to guideline version	SolarPACES Heliostat Performance Guideline v1.0
Report format	This report and data CD
Date, signature and stamp of testing lab.	

HELIOSTAT PERFORMANCE TEST – PARAMETERS (excerpt)

#	Full Parameter Name (Symbol)	Value	Unit	Meas.Technique	Measurement Report
1	HelioSetup.General.Type	T-shape	-	-	-
	...				
17	Optics.Conc. RealShape_SD_RMS	1.6	mrad	Deflectometry	MeasRep1.pdf
18	Optics.Conc. RealShape_SDx	CD	mrad	Deflectometry	MeasRep1.pdf
	...				
50	Cost.Specific	120	€/m²	-	CostReport.pdf

Results in:

- Main test report in tabular form with links to appended data, measurement report pdfs, graphs



Measurement Report

Slope Deviation Measurement

Further information appended in:

- Data format (in case of matrices, e.g.)
- Graphical form (in case of matrices, vectors, e.g.)
- Detailed measurement reports

4 To do‘s to get version v1 launched (I)

- The information contained in class-1 parameters is **complete** regarding **two-axis silvered glass mirror-steel heliostats**.

  For heliostats other than two-axis silvered glass mirror-steel heliostats, additional information is mandatory and must be included in class-1 list. For example:

  - **Heliostat with stretched membrane technology:**

    Par. Optics.Conc.DeformationByWind
  - **Heliostat with sandwich mirror panels:**

    Par. Optics.Conc.DeformationByTemperture
  - **Heliostat with reflective surface other than silvered glass:**

    Par. Optics.Reflectance.SolarWeightedSpecular

4 To do‘s to get version v1 launched (II)

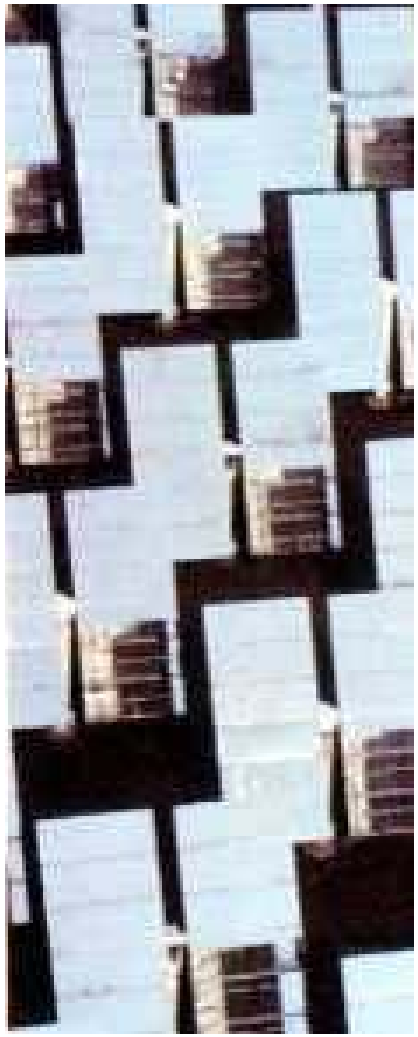
- Small section about *how to use* measured slope deviation values and tracker error in raytracer software:

„If raytracers accept matrices of slope deviation errors or reduced single values $SD_{x,STD}$ and $SD_{y,STD}$ for both *x* and *y*-direction, information of both directions should be used.

Raytracers which use Rayleigh distributions in radial direction (e.g. STRAL) only accept one input value for “sigma”.

This value then usually is
“sigma” = $SD_{x,STD} \cdot SD_{y,STD}$ / sqrt(2)
= $SD_{xy,STD}$ / sqrt(2).
Softwares should be listed

- Consistency check of guideline, smaller adaptations
- List of measurement techniques must be completed



The version working version v0.9 of the guideline can be downloaded from the SolarPACES-site, if you are participating into Task III.

Caution: Old links may be outdated. Currently, the site is moving.

THANK YOU for your attention
THANKS to all contributing persons

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DLR, Qualification, Systems